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Climate Adaptation: The future of extra-care housing for the elderly in the United Kingdom.



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Summary

This paper describes the result of a project to develop climate adaptation design strategies funded by the UK's Technology Strategy Board. The aim of the project was to look at the effects of climate change in the distant future (2080) on a vulnerable group such as older people with special needs and see how architectural design strategies and technologies may be used today to help mitigate problems ahead caused by climate change.

Older people are the most vulnerable sector of society and are particularly at risk in extreme weather, either excess cold in winter or continual high temperatures in summer. In the UK it is predicted that average temperatures may rise by as much as 8 degrees in Summer by 2080 and there will be a 20% greater chance of extreme weather events. This will place extreme stress on the building stock which is designed for today's mild maritime climate.

Keywords: architecture, climate adaptation, mitigation, facade, passive cooling, health.

1. Introduction

The project took a current proposal for an extra-care home for the elderly designed to 2010 regulations and developed a road map to 2080 using climate models developed by the UK Meteorological Office. This allowed the current design to be assessed using future climatic data, proposals for improvement of the scheme to be made within existing constraints and also a new scheme to be developed from first principals using this data, and projections of new technologies that will be available. By comparing these schemes, the approach allowed a reassessment of the initial scheme, and allowed a new design to be developed that offered a more flexible solution incorporating future retrofit which allows new renewable technologies for heating, cooling and water storage to be added at a later date.

2. Climate Adaptation.

Climate mitigation strategies by the UK Government are well under way, but even the most optimistic observers are aware that we are unlikely to be able to mitigate climate change now, as the effect of carbon emissions on climate can take more than 100 years to take effect. Because of this, the UK Government has taken steps to develop climate adaptation strategies to deal with future climate change. This paper describes a Technology Strategy Board funded project Design for future Climate: Adapting buildings, which investigates new strategies for designing resilient buildings, that can cope with the rigours ahead.

The fact is that the maritime climate of the UK, with its warm winters and cool summers is likely to become significantly warmer. This has little detrimental effect in winter, but in summer it is likely to be significant, as there are serious health issues related to elderly people during warm periods, particularly to those with circulatory issues, when extra stress on the body due to cooling needs

can cause amongst other things heart failure. In France, 15,000 extra deaths of elderly people occurred during a three-week August heatwave in 2003, with temperatures 4-5°C above normal.

From analysis of climatic prediction it is clear that by 2080 in the UK, the climate will be significantly different to that which have experienced up until now, with warmer drier summers and stormy winters. This will create severe problems for existing buildings, even those built today to the current UK standards.

By plotting temperature and humidity data on a psychrometric chart, a bioclimatic analysis of the predicted climate could be envisaged. Analysis of the dry summer year showed that by 2050 with a medium emissions scenario, there was a 50% chance (ie one year in two) that the summer would be similar in temperature and humidity to that of a Northern Mediterranean city, such as Nice, France. The extreme data for 2080 with a high emission Scenario with a 90% of not being exceeded, gave a very different summer climate, one more similar to Casablanca, Morocco. This scenario produced an average monthly temperature of 26.6 °C and 60.8 RH.

3. Conclusion

This climate change and the inability of the existing buildings to cope, will mean that elderly people will find it difficult to live healthily in the future due to severe overheating issues in summer. In addition, it is unlikely that a fixed design building built today will be able to adapt without massive change to the series of climates that will develop over the next 100 years.

This complexity of future climate, and the difficulty of accurate prediction, due to a range of emission scenarios and probabilities, makes the Climate adaptation of buildings a complex dialogue between environmental design and changing climate. The best strategy for adaptation is flexibility, particularly in façade design. The team developed a flexible approach that involved increased exposed thermal mass within the building with integrated flexible ventilation, and finally the future retrofit of façade cooling technologies, and green roofs.

The future flexibility for adaption via façade replacement is the preferred option as capital spending on climate adaptation technologies today is not a particularly good investment because there is too much uncertainty about the future climate and the key bioclimatic cooling strategies that may be needed. It will be more effective to operate a wait and see strategy, changing the façade when difficulties arise.

Finally, it would seem that passive solutions, integrated within well-designed buildings can cope with the future climate, and indeed there are many opportunities for technological and product innovations being developed from the issues identified.

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1. Introduction

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1.1 Climate and Health

The fact is that the maritime climate of the UK, with its warm winters and cool summers is likely to become significantly warmer. This has little detrimental effect in winter, but in summer it is likely to be significant, as there are serious health issues related to elderly people during warm periods, particularly to those with circulatory issues, when extra stress on the body due to cooling needs can cause amongst other things heart failure. In France, 15,000 extra deaths of elderly people occurred during a three-week August heatwave in 2003, with temperatures 4-5°C above normal [1].

However, it appears that our own physiological response to the stress, rather than the maximum temperature is what kills people, this may indicate that a high temperature in England might be more injurious to life than a similar temperature in Greece. It is possible that average temperatures may be up to 8 degrees higher in summer by 2080, yet most if not all of the UKs buildings are designed with cold weather in mind rather than hot[2]. Studies of heat related mortality from around the developed world[3] show a similar profile with a steep rise in mortality rates from approx 28 °C upwards. Exact trigger temperatures vary a little and this is generally attributed to cultural, technological and behavioural adaptation.

There are other issues created by this climate change. Rainfall is likely to change significantly, with an increase in winter and a greater reduction in summer. Summer rainfall could be as much as 40 % lower, and issues of water shortage will be a real problem. Compounding this are predictions of increased storm ferocity and frequency, which could cause flooding, landslip or structural damage.

1.2 The project

The building chosen for the study is an extra-care housing block in Leek, in NW England. Extra-care housing was defined by the Consultation Paper: "Future housing and care for older people" as 'Extra care housing supports older people to live independently and with dignity. It widens choice by providing older people with care and support in a housing-based setting, which meets their needs as individuals. Extra care housing schemes provide 24-hour support, meals, domestic help, leisure and recreation facilities and security.' [4]

Its main aim is to provide a lifetime home, which caters to the increasing needs of elderly people. Typically the developments consist of a number of self-contained apartments (typically 50-150), with social space, and community facilities. Care is available 24 hours per day. The building was chosen because its inhabitants are a growing sector of society, who are at high risk from climate change.

1.3 Existing climate

Table 1. Existing climate on site

Leek, Staffordshire UK.	January	July
Average daily Max Temp	6.0 °C	21.2 °C
Average daily Min Temp	0.3 °C	11.5 °C
Precipitation	55mm	47mm
Source: UN World Meteorological Organisation 2007 http://worldweather.wmo.int/010/c00028.htm		

The existing climate for Leek, UK, would be considered mild temperate maritime, with average January temps of 5°C and average July temperature of 15 °C. Rainfall is pretty constant all year round, leading to a constant humidity of around 80% in the morning and 60% in the afternoon.

1.4 UK Building Regulations

The summer climate is so mild that although new houses have high insulation levels (around 0.30 W/m²K for walls), and while the new regulations do not limit window area (except to recommend it should be over 20% of floor area), they do limit energy use for heating: houses are assessed by the amount of CO₂ they would produce in a year. For the first time overheating during summer is alluded to, but houses have no real requirement for any form of cooling, or shading, except to check their design to make sure it does not have 'a high risk of high internal temperatures'.

2. Future climate

The modelling of future climate is fraught with difficulties: there is still little agreement amongst climate scientists on models to use, and in fact climate is an inexact science where there can be large variation of result based on probability. In addition to this there are different carbon emission scenarios, which have a large effect on prediction.

In the UK the Department of Environment, Food and Rural Affairs, along with the UK Dept of Energy and Climate Change, have produced a range of Climate Projection scenarios known as UKCP09 [5]. These cover a range of years (2030, 2050, 2080), emissions scenarios (low medium high) and probability (33, 50 66 and 90 percent). The probabilities here are the likelihood of a certain climate being not exceeded, so the 90 percent model is the most extreme with only a 1 in 10 chance being exceeded.

From these scenarios, and by amplifying standard year data , a team at the University of Exeter have been able to produce predicted climate as a yearlong hourly set of results that mimic the CIBSE dsy (dry summer year) and try (test reference year) data used by many pieces of software. [6]. The scenarios are in the form of hourly data, in Energy Plus format (.epw) for use in most energy modelling software.

The project itself used a range of these data sources in its modelling. Firstly by plotting temperature and humidity data on a psychrometric chart, a bioclimatic analysis of the predicted climate could be envisaged. Analysis of the dry summer year showed that by 2050 with a medium emissions scenario, there was a 50% chance (ie one year in two) that the summer would be similar in temperature and humidity to that of a Northern Mediterranean city, such as Nice, France. The extreme data for 2080 with a high emission Scenario with a 90% of not being exceeded, gave a very different summer climate, one more similar to Casablanca, Morocco. This scenario produced an average monthly temperature of 26.6 °C and 60.8 RH.

Table. 2 Climatic summary for various climate scenarios

Climate Scenario for Birmingham, UK in July	Maximum Db Temp oC	Average Db Temp oC	Maximum Humidity %RH	Minimum Humidity %RH	Average Humidity %RH
2050, med emissions 50% TRY	29.9	18.5	100	30	82.6
2050, high emissions 50% DSY	30.7	19.4	100	38	70.0
2050, high emissions 90%DSY	36.5	22.2	100	27	63.0
2080, med emissions 50% TRY	29.8	19.5	100	38	74.1
2080, high emissions 50% DSY	33.0	21.5	100	26	60.9
2080, high emissions 90% DSY	38.5	26.6	100	28	60.8

What is apparent from the results is that future climate is due to change along a set curve and that the emissions scenario pushes the climate further along it. What this means is that a higher emission scenario for 2050, is broadly similar to a medium emission scenario for 2080 .

The average climate however tells us little about the day-to-day weather that will effect the buildings of the future. The bioclimatic analysis, using psychrometric data develops possible cooling strategies in a visual way [7].

2.1 Climate Visualisation

2.1.1 2050 Variations of predicted summer conditions.

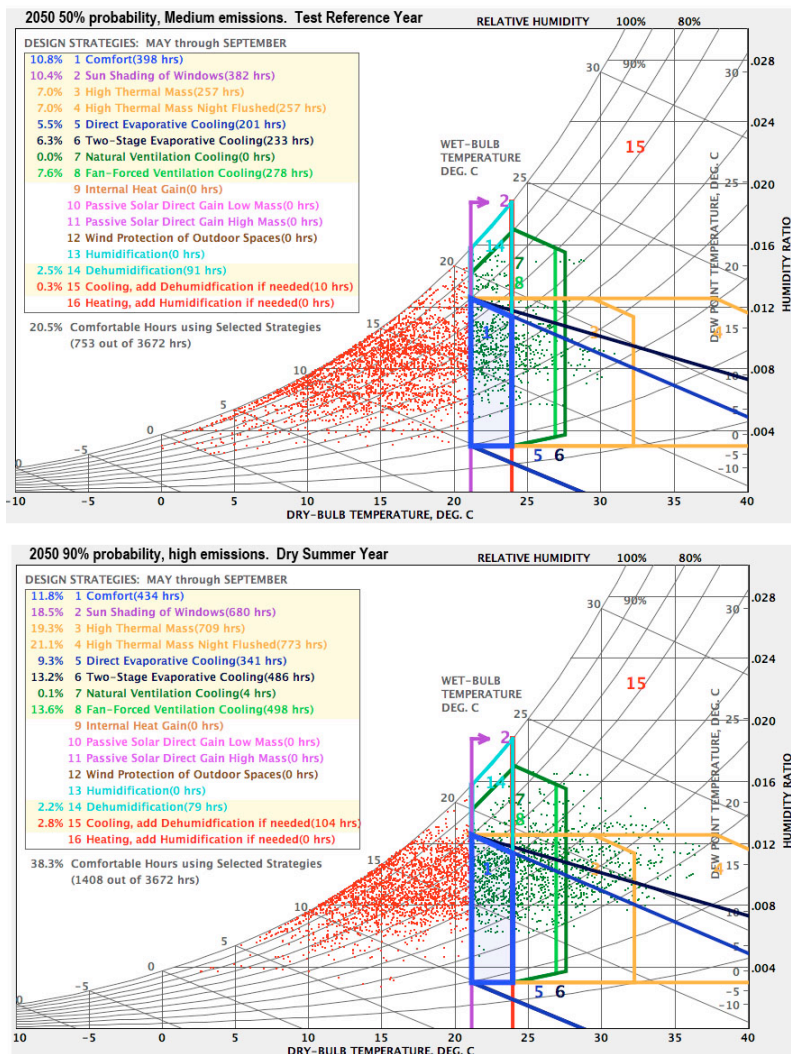


Fig 1. Comparison of 2050 predicted summer climates for Birmingham, UK.

2.1.2 2080 Variations on predicted Summer conditions

Once again, there is a wide variance of possible conditions that may occur and their frequency. The extremes of the high emission scenario are not matched by the medium emission test reference year.

What is clear from this analysis is that, although the future is uncertain, the climate will change more rapidly than ever before over the next Century. Worse still for architects and buildings – it

From the bioclimatic charts, we can see that the cooling strategies in 2050 vary wildly with the climate scenario. Comparing a medium emission scenario with a 1 in two year chance of happening with a 1 in 10 year high emissions scenario, shows that the summer climate moves from a broadly comfortable one, to one where some form of cooling is required.

For example a strategy using evaporative cooling might have some 820 hours use in a high emissions scenario, might be only used for less than half that time in a medium emissions scenario. A complex façade that could deal with the extreme of these scenarios would be expensive, and maybe not necessary, depending how the climate unfolds. This uncertainty leads to difficulties in the accurate specification of technologies at the present time.

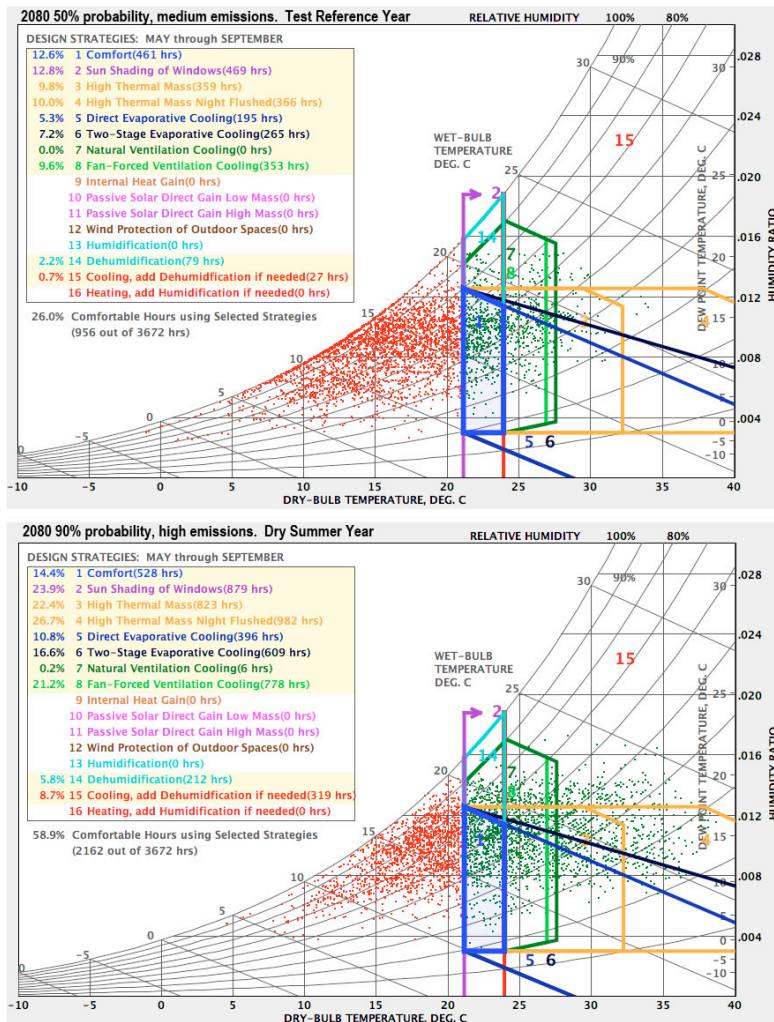


Fig. 2: Comparison of 2080 predicted summer climates Birmingham UK

It is clear that lightweight building construction methods such as timber-frame construction will not provide the correct environmental response, for the future climates of the UK. Which is interesting given the incredible take up of timber framed technologies in the UK

3. British Trimmings Extra-care Housing

3.1 The existing house

The Extra care housing acting as a test case for adaptation, had already been designed to a detailed specification. Indeed so far advanced was the design, that the building had already receive both planning approval and building regulations compliance and a detailed cost-plan had been developed.

The building is typical of many modern housing developments in the UK, The system of construction is 'traditional': Load-bearing brick & block external and party walls with plasterboard dry lining, with precast concrete upper and ground floor slabs with suspended plasterboard ceilings and under-floor heating (from a centralized plant) set in screed. Internal partitions would be timber or metal stud framed with plasterboard, timber and tiled pitched roof.

will mutate across meteorological zones, and their passive and vernacular solutions: from Maritime Temperate, to Mediterranean to Sub-Saharan. Whilst vernacular building solutions have evolved over hundreds of years, we are now faced with engineering new solutions for this period of rapid change where we may look to other regions for some precedence but must also deal with a different mix of variables such as high temperatures, lower more penetrative sun angles and increased storm conditions for example. This creates severe problems, for buildings, which in the UK at least are designed to last 60 years and often in the case of dwellings, survive much longer indeed. Indeed, from a bioclimatic strategy viewpoint with regards cooling, it could be conceivable that during the life of the building, the optimum strategy for cooling could range from evaporative, for some scenarios, or ground cooling with dehumidification for others.

Compounding this is the uncertainty: clients and developers are unlikely to want to install expensive systems now, especially if they will not be needed for some time- and maybe not at all. However, one thing all the graphs have in common though, is the effectiveness of thermal mass in all the cases to help provide comfort.

The façade was over 30% glazed, but the building would meet the UK Building Regulations and exceed BREEAM Very Good.



Fig. 3 View of Existing building

Tendering contractors would have the opportunity of offering a timber frame alternative price all under a Design & Build procurement route. There was initial concern that the ‘medium-weight’ construction proposed *could* have, and a timber frame ‘lightweight’ alternative *would* have problems of overheating under current conditions if no mitigation measures were introduced.

The apartments themselves were single aspect, off a double-banked corridor, which is an economic reality given the ratios of circulation to amenity space acceptable to various funding regimes. This gave each room in the dwelling the same orientation, although many apartments had different orientations due to the cruciform and courtyard building layout. It was decided to model two back-to-back sections of the building particularly where the orientation would create the most overheating and apartments facing SW and NE were thus chosen.

3.2 Option 1 – Adapted original design

The first scenario studied was to consider a modestly adapted design which could be achieved within current Planning Permission constraints, and see how much improvement could be made by simple changes to the building, without much external aesthetic change. This included addition of some internal vertical vent stacks to improve cross and stack ventilation through the flat either naturally or fan assisted.

Computer modelling of the existing and adapted apartments with XXX software showed that overheating to a dangerous level would occur, not only with high emission scenarios in 2080, but also with lower emissions and earlier dates. Comparative modelling studies were conducted to test the relative effects of:

- thermal mass - light, medium and heavy weight constructions
- ventilation rates – 2, 4 & 6 air changes/hour.

Table 3: Existing building/facade performance

Modelled performance of existing design options for differing climate scenarios
Room 2nd floor living Room SW facing

Construction Type	Climate Scenario	Cumulative Hours over 25degC	Cumulative Hours over 28degC	Max Room temp (degC)
1a existing building mediumweight construction	2010 current design standard	131	24	30.86
	2050 medium emissions 90% probability	705	189	33.43
	2080 medium emissions 90% probability	1206	349	33.48
1b modified building high thermal mass	2010 current design standard	84	11	29.63
	2050 medium emissions 50% probability	644	116	31.17
	2080 medium emissions 90% probability	1248	297	31.98
1c modified building high thermal mass 4ach passive stack vent	2010 current design standard	46	6	29.9
	2050 medium emissions 50% probability	631	134	32.22
	2080 medium emissions 90% probability	1140	280	32.45

Serious design changes would be needed if the building were to meet recommended thermal conditions for health in the future.

3.3 The strategy.

Older people are more likely to have difficulty utilizing complex unfamiliar systems, particularly those in buildings. In this case the brief was to keep the system as simple and user controlled as possible, but still utilizing passive means. The client as a long term building owner and service provider has a real interest in increasing the resilience of their new building stock and reducing the risks of redundant assets or high cost, carbon intensive future adaptations eg. Air conditioning.

3.4 Option 2: rationalised design

The second scenario was, given removal of previous constraints but a broadly similar site arrangement, to rationalise the design in plan, section and construction from lessons learnt in the Option 1 study.

3.4.1 Flexibility

The strategy for the re-design of the building for adaptation, was first based around flexibility. If the climate is going to change so rapidly during the life of the building, then it is likely that the building will have to accommodate, many differing ways of dealing with the change. In addition, as during this time our dependence on fossil fuels will have to reduce, most of the solutions will have to be of a passive nature. This means the façade will have to become the adaptive part of the building.

3.4.2 Façade.

The original façade was load-bearing brick and block – with a u-value of 0.27 W/m²K – designed to meet winter design conditions. Due to its load-bearing nature, it would be almost impossible to change during the life of the building, so a decision was taken to change the structural system of the building, and allow the façade to be a curtain wall type, or possibly free-standing, to allow for easy change. The new façade was designed to be replaced every 25 years (and possibly more frequently) so it could keep up with the changing climate. The design team believe that better predictions of future climate will be available in the future and the direction of actual climate change trends will be clearer as the reality unfolds. This strategy will allow the building to be re-designed to meet those needs nearer the time.

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3.4.3 Thermal Mass and green roof

Once the new structure was agreed, the next decision was to increase the amount of thermal mass inside the insulation envelope to improve passive performance. By introducing dense concrete cross-walls the building mass could be increased, this could then be extended by using a concrete slab and beam floor throughout the building, rather than a timber floor. By using fair-faced slabs, it was possible to expose the underside of the slab – giving each flat a heavyweight ceiling, exposing the mass. Indeed the decision was taken to place a concrete ceiling at the top floor, before the timber pitch roof was assembled to keep the thermal weight of each storey about the same. It also allowed for the introduction of substantial flat green roof areas to contribute to water collection/attenuation. The asymmetrical section includes for southerly facing pitched roofs with PV and thermal solar collectors and gives roofspace for building services.

3.4.4 Ventilation.

Initial analysis of the ventilation of the apartments, suggested that single-sided ventilation might not be sufficient to provide enough air changes per hour, without disturbing the residents. It was decided that flexibility of mode of operation might be compromised if the building only relied on single sided ventilation.

Taking inspiration from MacCormac Jamieson and Pritchard's Wood Green Mental Health Centre [8], it was decided to build the structural cross walls as diaphragm walls. The voids in the wall could then be used as either inlet or extract for air, depending on future needs.



Fig. 6: Wood Green Mental Health Centre.

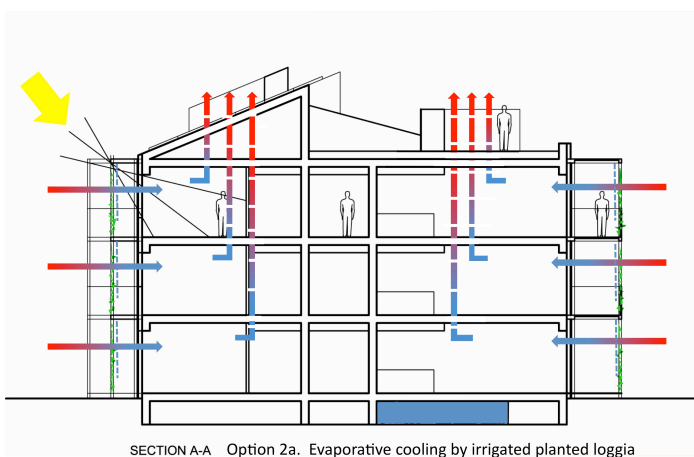
This system allowed more flexibility and better airflow through the apartment, without noise issues, and allowed the façade to either supply or extract air if it was needed. The system was also designed with access to the base of the walls, so if a ground cooling system was to be introduced at a later date, it could be without issue.

3.4.5 Dealing with uncertainty: Replacement facades

Analysis of the bioclimatic data, showed that there was likely to be two main cooling strategies in the future for the building, beyond thermal mass, ventilation and shading. These would involve evaporative cooling and ground cooling, possibly with dehumidification. The second part of the research, would test the flexible design, by developing two new facades, that could be retrofitted as an adaptation strategy. Façade one would look at evaporative cooling using a planted free-standing external loggia, with irrigation system. The second system would utilise ground cooling, assisted by solar chimney extract. The development and testing of these 'blue-sky' solutions would demonstrate the flexibility of the design in coping with climate change.

3.5 Final façade options

3.5.1 Option 2a: Green loggia with irrigation system



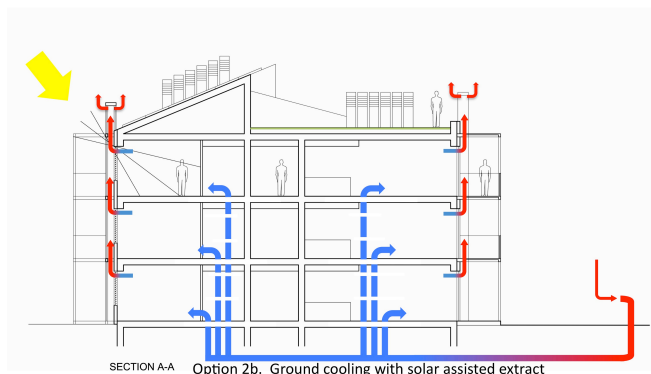
This system consists of a timber loggia with balconies, with a planted green sunshade where water trickles constantly down the plants. This allows some mass-transfer to occur, cooling the air. In addition, the planting creates a sense of cool external to the property. Extract air is taken up the diaphragm wall inside the dwelling.

The system worked particularly well in the hot dry summer scenario, where the evaporative cooling via the irrigation system within the planted façade could be most effective. A large water store under the building is essential in this configuration to reduce water usage in summer.

Fig. 7: Adapted façade for hot/dry conditions

3.5.2 Option 2b: Ground Cooling with solar extraction

In this system, it is possible to adapt the building utilising ground cooling. The diaphragm wall has been design so that a labyrinth through the ground external to the building can be connected to the base of it. The ground temperature, even in the most extreme weather of the 2080 model, does not exceed 17°C, so substantial cooling could be gained from this. Air is then drawn through this system pulled by glazed solar chimneys built into the new façade, and if necessary a pv-powered fan. The green roof helps to reduce heat gain on part of the roof, whilst the South-facing pitch offers a chance for energy collection.



The system is most effective in hot climates with a higher humidity, where evaporative cooling is ineffective. The two option help prove the flexibility of the design, as in each, the diaphragm is used differently, in this case as a supply, and as an extract in Option 2a.

The thermal modelling results for these two design options are shown in Table 4. There is a very much reduced internal temperature and duration expected in each model.

Fig. 8 Adapted façade for hot/humid conditions

Table 5: Results for retro-fitted facades, for differing climate scenarios

Modelled performance of adapted design options for differing climate scenarios

Room 2nd floor living Room SW facing

Construction Type	Climate Scenario	Cumulative Hours over 25degC	Cumulative Hours over 28degC	Max Room temp (degC)
2a Evaporative cooling stack extract	2010 current design standard	13	0	27.9
	2050 medium emissions 50% probability	322	48	28.7
	2080 medium emissions 90% probability	644	151	29.2
2b Ground cooling solar extract	2010 current design standard	5	0	27.1
	2050 medium emissions 50% probability	301	40	28.8
	2080 medium emissions 90% probability	407	87	28.9

4. Discussion and Conclusions

From analysis of climatic prediction its is clear that by 2080 in the UK, the climate will be significantly different to that which have experienced up until now, with warmer drier summers and stormy winters. This will create severe problems for existing buildings, even those built today to the current UK standards.

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